



6FKRODUV 5HVH DUFK /LEUDU\

\$QQDOV RI %LRORJLFD O 5HVH DUFK

KWWS ZZZ VFKRODUVUHVH DUFKOLEUDU\ FRP

,661

(IIHFWV RI 1LWURJHQ DQG 3KRVS KRUXV 0LFUR 'R  
LQ D 6XE +XPLG 7URSLFDO &OLPDWH

3DXO 6 6DLGRUDQHO / 5ZH)RDN D XG - \$KQV RQ 05 6\$P RNDQ\  
\$ .LPDURRUQ \*HU)PHLUGHU 30BHHQLQ)UDJZHLQ .DKLPED  
(PPDQXHO \$ &KLODJDQH

\$JULFXOWXUH 5HVH DUFK ,QVWLWXWH \$5, 8NLULJXUX

'HSDUWPHQW RI &URS 6FRORH DQG 6FLYHU VLVWV DQJLJURXOV  
,QVWLWXWH IRU 3ODQW 3URGXFWLRQ DQG \$JUR HFRORJ\ LQ WKH 7U  
\*HUPDQ\

'HSDUWPHQW RI 6RLO DQG \*HFRORJLFD 6FLYHU VLVWV DQJLJURXOV  
:RUOG \$JUR )RUHVWU\ &HQWUH ,&5\$) &RXQWU\ +HDG 2IILFH  
=\$/) ,QVWLWXWH RI /DQG 8VH 6\ VWHPV 0ÖQFKHEHUJ  
\$5, ,ORQJD .LORVD 0RURJRUR 7DQJDQLD

'HSDUWPHQW RI (QJLQH HULQ 6FRORH DQG 6FLYHU VLVWV DQJLJURXOV

\$%675\$&7

,QDGHTXDWH NQRZOHGJH RQ IHUWLQJHU XVDJH DQG SRRU ILQDQI  
SURGXFWLYLW\ XQGHU VPDOO VFDOH IDUPLQJ )HUWLQJHU PLFUR G  
ZKLFK DUH DIIRUGDEOH E\ PRVW UHVRXUFH SRRU IDUPHUV DQG KDYH  
ZDV FRQGXFWHG RQ VDQG\ ORDP DQG VDQG\ FOD\ VRLOV EHLQJ W  
HFRORJLFD JHQHV \$ VSOLW SORW GHVLJQ LQYROYHG GL DPPRQLX  
VXSHU SKRVSKDWH 763 DV PDLQ SORWV DQG IHUWLQJHU PLFUR GRVH  
3 KD NJ 1 DQG NJ 3 KD NJ 1 DQG NJ 3 KD UHFRPPRQWUO  
VXE SORWV 3KRVS KDWH IHUWLQJHUV WKDW SURGXFHG KLJKHVW JU  
NJ KD DQG 763 NJ KD )HUWLQJHU PLFUR GRVH UDWHV NJ 1  
WKH \LHOG E\ DQG IURP NJ KD LQ FRQWURO UHVSHFWLY  
DQG NJ 1 DQG NJ 3 KD SURGXFHG DYHUDJH JUDLQ \LHOGV RI  
SURGXFHG NJ KD 7KH KLJKHVW JUDLQ \LHOG ZDV NJ KD IURP  
PLFUR GRVH RSWLRQV WKUHIRUH 00 IHUWLQJHU DQG PLFUR GRVH  
3 KD DUH UHFRPPHQGHG LQ WKHVH DJUR HFRORJLFD JHQHV

.H\ZRUG IHUWLQJHU PLFUR GRVLQJ \*URZWK DQDO\VLV FKDUDFWHULV  
5HODWLYH DJURQRPLF HIIHFWLYHQHV

,1752'8&7,21

0DLJHHD P\VLV WKH PRVW SRSXODU DQG LPSRUWDQW FURS LQ 7DQ  
FRXQWULHV DV LW LV JURZQ IRU IRRG DQG FDK 7KH HVWLPDWHG D  
SHUVRQ \HDU > @ EXW WKH DYHUDJH PDLJH \LHOG LV W KD ZKL  
ORZ \LHOG OHDGV WR SHUSHWXDO VHOI LQVXIILFLHQF\ LQ PDLJH DYD

/RZ PDLJH SURGXFVLYLW\ LV DWWULEXWHG PDLQO\ WR GHFOLQLQJ V  
&RQWLQXRXV IDUPLQJ DQG ORZ RU QR XVH RI IHUWLLOLJHU DFFHOHUI  
LQRUJDQLF IHUWLLOLJHUV ZKHUH WKH PDLQ QXWULHQW VXSSOLHG LV  
PRVW OLPLWLQJ QXWULHQWV LQ PDLJH IDUPLQJ > @

5HDVRRQV IRU ORZ IHUWLLOLJHU DGRSWLRQ LQ FURS SURGXFVLRQ E\  
IHUWLLOLJHU XVDJH VXFK DV W\SH UDWK WLPK PHWKRG DQG IHUV  
UHVXRUFH SRRU WKHUHIRUH WKH\ FDQQRW DIIRUG WR EX\ DQG DS  
QHFHVVLWDWHV WKH QHGH WR LQWURGXFH WKH IHUWLLOLJHU PLFUR  
DGGUHVHV IHUWLLOLJHU SODFHPHQW ZLWK D UDWK RI DERXW D WKL  
DGYLVRU\ VHUFLFHV > @ 0LFUR GRVH WHFKQRORJ\ HQDEOHV IDUPHU  
JUDGXDOO\ PRYH WR KLJKHU FDSLWDO LQWHQVLYH WHFKQRORJLHV D  
UHGXFHV WKH ULVN RI FURS IDLOXUH DQG IHUWLLOLJHU SRLVRQLQJ L  
> @ \$ ORQJ WHUP VWXG\ RQ WKH XVH RI IHUWLLOLJHU PLFUR GRVH L  
RQ KLJKO\ GHJUDGHG VRLO LV LPSURYHG E\ FRPELQHG DSSOLFDWLR  
RQ WKH XVH RI IHUWLLOLJHU PLFUR GRVLQJ WHFKQRORJ\ E\ VPDOOKR  
FRXQWULHV > @ 7KHVH VWXG\HV IRLUWLQJ WKDW ZDV D \$ \$UDR \$UDW  
VRUJKXP DQG PLOOHV FXOWLYDWHG XQGHU VHPL DULG FRQGLWLRQV  
8UHD KD LQ VHPL DULG (3WKL DULG) > @ Q 13XPUG IRUHVW DUHDV LQ \*K  
DQG NJ 3 KD LQ .HQ\ D > @ DV PLFUR GRVH IHUWLLOLJHU UDWHV L  
PXOWLSOH QXWULHQWV IHUWLLOLJHUV VXFK DV 00 ZKLFK VXSSOLHV E  
FRQGLWLRQV DW PLFUR GRVH UDWHV GHYHORSHG IRU VPDOOKROGH  
7KHUHIRUH WKLV VWXG\ ZLOO SURYLGH LQIRUPDWLRQ DERXW VWUDL  
PDLJH SURGXFVLRQ XQGHU VXE KXPLG WURSLFDO DUHDV

)LHOG H[SHULPHQWV ZHUH FDUULHG RXW LQ WZR FDVH VWXG\ YLOOD  
FRPSDUHG DJDLQVW IDUPHUV SUDFWLFHV DQG QLWURJHQ 1 DQG 3  
VWXG\ LQYROYHG XVH RI GLIIHUHQW W\SHV RI 3 IHUWLLOLJHUV FRPSD  
DV WR SURYLGH PLFUR QXWULHQWV ZKLFK DUH LQFUHDVLRQ\ EFR  
WKH IUDPHZRUN RI D ODUJH SDUWLFLSDWRU\ UHVHDFK SURMHFW >  
IHUWLLOLJHU PLFUR GRVLQJ UDWHV WKDW ZRXOG EH DIIRUGDEOH E\  
LQYHVWPHQW UHWXUQ 2EMHFWLYHV RI WKH VWXG\ ZHUH WR GHWHU  
RQ PDLJH JURZWK DQG \LHOG XQGHU GLIIHUHQW VRLO FRQGLWLRQV  
DQG \LHOG RI PDLJH

0\$7(5,\$/6 \$1' 0(7+2'

'HVFULSWLRQ RI WKH VWXG\ DUHD

7KH VWXG\ ZDV FRQGXFWHG LQ .LORVD 'LVWULFW 0RURJRUR 5HJLRQ  
5DLQIDOO WKHUH LV ELPRGDO ZKHUH WKH VKRUW UDLQ VHDVRRQ VWD  
VWDUWV IURP PLG )HEUXDU\ DQG HQGV LQ 0D\ 7KH PHDQ DQXDO U  
DYHUDJH DPELHQW WHPSHUDWXUH LV DERXW f & > @ 7KH H[SHULP  
f K Š( DQG P DERYH VHD OHYHO LQ 0D\ 0D\]H ZDUG DQG ,ODN  
DERYH VHD OHYHO LQ 8OOD\ D ZDUG 7KH YLOODJHV DUH ORFDWHG

([SHULPHQWDO GHVLJQ WUHDWPHQWV DQG PDQDJPHQW

0DLJH YDULHW\ XVHG ZDV 709 239 WDNLQJ GD\ V WR PDWXUH  
DPPRQLXP SKRVSKDWH 2 \$3 WK1+ 1 DQG > @3 0LQMLQJX 0D]DR 00  
1 DQG 2 3 &D2 6 0J2 =Q DQG % > @ DQG WULSO  
FRQWDLQGDQG3XUHD ZKLFK KDG 1 > @

([SHULPHQWV ZHUH LQLWLDWHG LQ 'HFHPEHU DQG )HEUXDU\  
7KH ILHOG H[SHULPHQWDO GHVLJQ ZDV D VSOLW SORW ODLG RXW L  
PDLQ SORW ZDV SKRVSKDWH IHUWLLOLJHUV WKDW ZHUH '\$3 00 DQG 7  
QR IHUWLLOLJHU XVH DV IDUPHU SUDFWLFH PLFUR GRVH UDWHV N  
UDWHV NJ 3 DQG NJ 1 KD NJ 3 DQG NJ 1 KD DQG UHFRPPH

DQG 763 IHUWLOLJHUV ZHUH DSSOLHG E\ VHSUDUDWH KROH SODFHP  
 LQFRUSRUDWLRQ LQWR WKH VRLO EHFDXVH RI ORZ VROXELOLW\ > @  
 FURS VSDFLQJ XVHG ZDV P E\ P ZLWK URZV SHU SO\$WW DQG  
 ,ODNDOD VLWH PDL]H FURS ZDV VRZQ RQ -DQXDU\ DQG -DQ  
 GRQH RQ 0DUFK DQG -DQXDU\ E\ GLEEOLQJ PHWKRG 7ZR  
 GRQH DW VHHGOLQJ VWDJH 9 \$JURQRPLF SUDFWLFWV DQG FURS PI  
 VHHGOLQJ VWDJH 9 ILIWK OHDI VWDJH 9 DQG WDVVHOLQJ 97 6  
 VSUD\LQJ LQVHFVWFLGH .81\* )8 (& J / /DPEGD F\KDORWKULQ E\  
 VDFN VSUD\HU > @

'DWD FROOHFWLRQ

6RLO VDPSOLQJ DQG ODERUDWRU\ DQDO\VLV

6RLOV ZHUH VDPSOHG EHIRUH HVWDEOLVKLQJ H[SHULPHQWV DQG DQ  
 FP DQG FP 4XDUWHULQJ PHWKRG ZDV XVHG WR JHW FRPSRVL  
 /DERUDWRU\ IRU DQDO\VLV 6RLO DQDO\VLV LQFOXGHG SDUWLFQH VL  
 S+ E\ S+ PHWHU LQ VRLO ZDWHU RUJDQLF FDUERQ E\ :DONOH\  
 GLJHVWLRQ PHWKRG DYDLODEOH SKRVSKRUXV E0J%UDYDQG 1.XUW]  
 DFHWDWH ILOWUDWHV E\ DPPRQLXP DFHWDWH VDWXUDWLRQ DQG DY  
 H[WUDFWLRQ PHWKRG

:HDWKHU GDWD

\$W ERWK VLWHV GDLO\ ZHDWKHU GDWD RQ UDLQIDOO PP ZDV UHFR  
 WKH H[SHULPHQWDO ILHOGV GXULQJ WKH DQG FURSSL

1XWULHQW FRQFHQWUDWLRQ DQG XSWDNH LQ SODQWV

)LYH SODQWV ZHUH VHOHFWHG UDQGRPO\ DW VL[WK OHDI JURZWK V  
 GHVFULEHG E\ +RFKPXWK HW DO > @ 6DPSOHV ZHUH RYHQ GULHG  
 )DJHULD HW DO > @ 7KH QXWULHQWV DQDO\VHG LQFOXGH 1 3 .  
 XVLQJ WKH HTXDWLRQ GHVFULEHG E\ )DJHULD HW DO > @ ZLWK VR  
 ZHUH FKDQJHG LQWR PJ NJ E\ PXOWLSO\LQJ E\ DQG ODWHU RQ F  
 JHW NJ QXWULHQW KD DV IROORZV

1XWULHQW XSWDNH NJ KD 7'0 NJ KD î 1XWULHQW FRQWHQW LQ SO

\*URZWK DQDO\VLV DQG WRWDO GU\ PDWWHU

\*URZWK DQDO\VLV FKDUDFWHULVWLFV ZHUH GHWHUPLQHG E\ VDPSOH  
 VLONLQJ 5 DQG GRXJK JURZWK VWDJH 5 > @ /HQJWK DQG ZLGW  
 /\$ ZDV FDOFXODWHG IURP WKH HTXDWLRQ GHVFULEHG E\ 2JRNH HW

/\$ /HQJWK RI OHDI FP î 0D[LPXP ZLGWK RI OHDI FP î D FRQVW

7RWDO GU\ PDWWHU 7'0 ZDV GHWHUPLQHG DV GHVFULEHG E\ &,00  
 \$GYDQFHG (OHFWURQEF. %DQDQRHUR\$'(JURZWK UDWH &\*5 DQG OHDI  
 GHWHUPLQHG XVLQJ WKH PHWKRGV > @ DV IROORZV

/\$, /\$ \*\$

$$CGR = \frac{1}{GA} \times \frac{W2 - W1}{T2 - T1} J P GD \setminus$$

:KHUH \*\$ LV JURXQG DUHD FRYHUHG /\$ LV OHDI DUHD 7 DQG 7 DU  
 : DUH ZHLJKWV RI GU\ PDWWHU DW GLIIHUHQW JURZWK VWDJHV

7RWDO GU\ PDWWHU 7'0 DW VL[WK OHDI JURZWK VWDJH 9 VLONL  
 GHWHUPLQHG E\ VDPSOLQJ ILYH SODQWV UDQGRPO\ DQG RYHQ GU\LQ

<LHOG FRPSRQHQWV DQG JUDLQ \LHOG

<LHOG FRPSRQHQWV GHWHUPLQHG LQFOXGHG SODQW SRSXODWLRQ D  
P DQG VHHG VLJH J VHHGV <LHOG LQYROYHG WKH ELRORJLFDO  
JUDLQ \LHOGV LQWHVW PDWXULW\ > @

'DWD DQDO\VLV

6RLOV ZHDWKHU DQG QXWULHQW FRQFHQWUDWLRQ GDWD ZHUH VXE  
&URS JURZWK DQG \LHOG GDWD ZHUH DQDO\VHG "XVLQJ EDVLF DQDO\VLV  
VWDWLVWLFDO PRGHO IRU WKH VSOLW SORW GHVLJQ DV IROORZV

<LMN L \$M /LM %N \$%LN OLMN

:KHUH <LMN 5HVS\*RIQVHU DQYHIOHFWRU JHQURIDQ HIIHURW \$HVLQD LQKSOR  
PDLQ SORW UDQGRP HUURU (UURU D %N 6XE SORW HIIHFWRU \$%LN ,  
DQG OLMN 6XE SORW UDQGRP HUURU HIIHFWRU (UURU E

&RPSDULVRQ RI PHDQV ZDV GRQH ZLWK GHYFUHLFV GHVHW D&RIS IILFLHQW  
DQG FRUUHODWLRQ FRHILFLHQW U DQDO\VLV IRU PLFUR GRVH IHUW

5HODWLYH DJURQRPLF HIIHFWLYHQHV IRU 00 IHUWLQJHU DV D WH  
FDOFXODWHG XVLQJ WKH HTXDWLRQ GHVFULEHG > @ DV IROORZV

5HODWLYH DJURQRPLF HIIHFWLYHQHV 5\$(

=((Yield from test fertilizer - Control yield / Yield of standard fertilizer - Control yield) x 100%)..(6)

5 (68/76

6RLO DQG ZHDWKHU GHVFULSWLRQ

6RLO FKDUDFWHULVWLFV DW WKH VWXG\ VLWHV DUH VKRZQ LQ 7DEOH  
DW FP DQG FP UHVSHFWLYHO\ 6RLO S+ ZDV QHXWUDO  
RUJDQLF FDUERQ DQG SKRVSKRUXV PJ NJ ([FKDQJHD  
VRGLXP ZKLFK ZDV ORZ 0LFURQXWULHQWV GHWHUPLQHG ZHUH PHGL  
6RLOV DW &KDQJDUDZH VWXG\ VLWH ZHUH VDQG\ FOD\ ORDP DQG VDO  
ZDV PHGLXP DFLGLF 7RWDO QLWURJHQ 1 RUJDQLF FDUERQ 2

Table 1: 6RLO FKDUDFWHULVWLFV DW ,ODNDOD DQG &KDQJDUDZH VWXG\ VLWHV  
/HWWHUV LQ SDUHQWKHVLV UHSERFHUHQW D EYRU DYDORQ RQ @RZKHU FD+DQWLUK LJK/RZ 0  
9HU\ /RZ

6RLO FKDUDFWHULVWLFV ,ODNDOD	,ODNDOD	&KDQJDUDZH	&RQJDUDZH	FP
Sand (%)	66.24	69.52	62.24	77
Clay (%)	26.48	26.48	30.48	14
Texture class	Sandy Loam	Sandy Clay	Sandy Clay Loam	Sandy Loam
Soil pH	6.92 neutral	7.10 neutral	5.52 strongly acid	5.33 strongly acid
Total nitrogen (%)	0.10 L	0.20 L	0.06 VL	0.04 VL
Organic carbon (%)	2.09 M	2.00 M	0.93 L	0.80 L
P-Bray 1 (mg/kg)	19.77 M	10.21 M	2.86 L	2.75 L
Exchangeable potassium (cmol+/kg)	1.15 H	0.64 M	0.80 M	0.72 M
Exchangeable magnesium (cmol+/kg)	0.75 M	0.70 L	1.89 H	1.72 H
Exchangeable calcium (cmol+/kg)	13.77 VH	15.23 VH	3.89 M	3.89 M

Exchangeable sodium (cmol+/kg)	0.10 L	0.09 VL	0.24 L	0.26 L
Copper (mg/kg)	0.36 M	0.26 M	0.24 M	0.26 M
Zinc (mg/kg)	0.58 L	0.34 L	0.91 M	0.58 L
Iron (mg/kg)	20.73 H	13.45 H	38.76 H	41.68 H
Manganese (mg/kg)	43.30 H	36.70 H	42.80 H	47.50 H

5DLQIDOO UHVXOWV IRU DQG FURSSLQJ VHDVVRQV DUH RI UDLQIDOO LQ FURSSLQJ VHDVVRQ ZDV PP ZKLOH LQ DV ZHOO DV LQWUD VHDVVRQDO YDULDWLRQ LQ UDLQIDOO DPRXQW WKHUH ZHUH QR UDLQV ZKLFK FRLQFLGHG ZLWK VHHGOLQJ DQG WKHUH ZDV KLJK UDLQIDOO ZHHNV DIWHU SODQWLQJ )URP VLON DIWHU SODQWLQJ WKHUH ZDV PRGHUDWH DPRXQW RI UDLQIDOO UDLQIDOO LQFUHDVHG IURP PP DW HPHUJHQFH WR PP DW IRXUV WDVVHOLQJ VWDJH WR ZHHNV DIWHU SODQWLQJ )URP PLON VWDJH DPRXQW ZDV YHU\ KLJK PP "

,Q &KDQJDUDZH WRWDO DPRXQW RI UDLQIDOO UHFHLYHG ZDV PP 'XULQJ FURSSLQJ VHDVVRQ WKHUH ZDV ORZ UDLQIDOO DW HPHUJHQ UDLQV DPRXQWLQJ WR PP DW HPHUJHQ UDLQV SODQWLQJ UHV VWDJH WR PLON VWDJH WR ZHHNV DIWHU SODQWLQJ WKHUH ZDV DQG PDWXULW\ VWDJH ,Q DPRXQW RI UDLQIDOO LQFUHDVHG IURP DQG GHFUHDVHG UDSLGO\ WR DERXW PP DW HPHUJHQ UDLQV SODQWLQJ

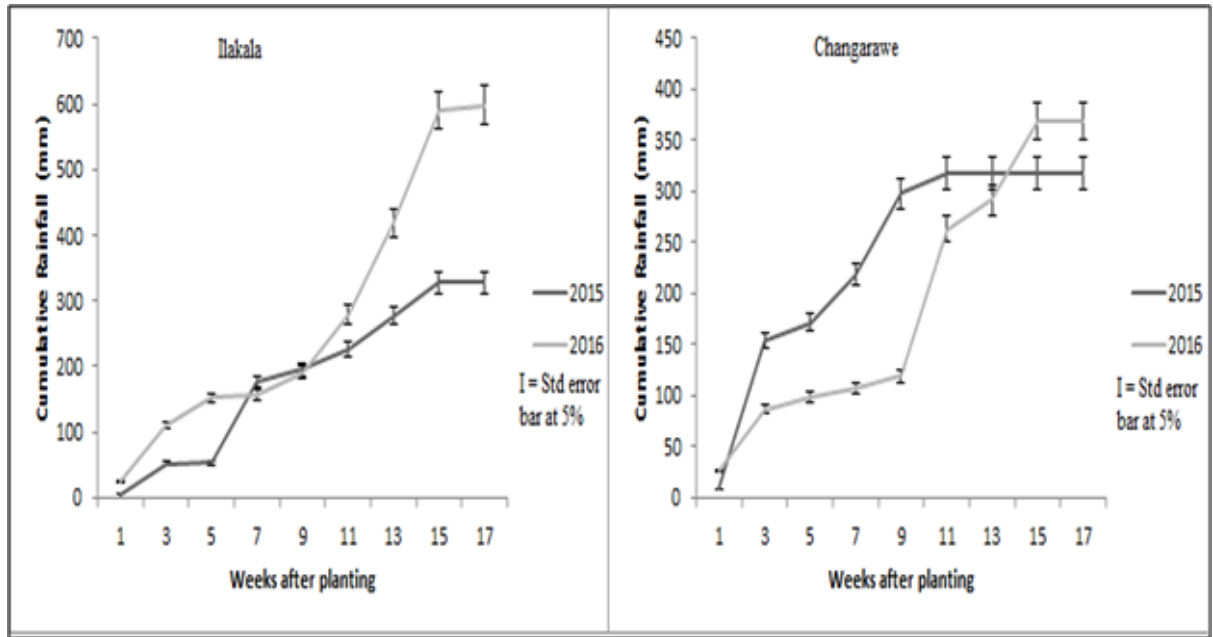


Figure 1: 5DLQIDOO DPRXQW DQG GLVWULEXWLRQ GXULQJ PDLQ VHDVVRQ DIWHU 1XWULHQW FRQFHQWUDWLRQV LQ PDLJH SODQWV

'LIIHUHQW IHUWLLOL]HU W\SHV DQG PLFUR GRVH UDWHV VLJQLILFDQW GXULQJ DQG DV VKRZQ LQ 7DEOH 1LWURJHQ 1 FRQFHQWUDWLRQ UDWHV ZLWK PD[LPP DW UHFRPPHQGHG UDWH GXULQJ ZKLOH GX 3KRVSKRUXV 3 FRQFHQWUDWLRQ LQFUHDVHG IURP FRWURO WR IH DQG UHFRPPHQGHG UDWHV GXULQJ DQG \HDUV &RQFHQWUDWLRQ GLIIHUHQW IHUWLLOL]HU UDWHV DQG UHDFKHG PD[LPP DW PLFUR GR 6XOSKXU 6 FRQFHQWUDWLRQ LQFUHDVHG IURP FRWURO WR PL

LQ '\$3 00 DQG 763 SORWV =LQF =Q FRQFHQWUDWLRQ KDG LUUHJXC  
 DQG GHFUHDVHG WRZDUGV UHFRPPHQGHG UDWLQ 00 '\$3 DQG 763 I

**Table 2:** 1XWULHQW FRQFHQWUDWLRQ LQ PDL]H SODQWV DW ,ODNDOD VLWH  
 '\$3 LV 'L \$PPRQLXP 3KRVSJDWH 0000 763-1V870\$SS2 6XSHU 3KRVSJDWH IHUWLQ]HU  
 IDUPHUV QRW DSSO\LQJ IHUWLQ]HU DQG DQG NJ 1 KD DQG 3 KD UHVSHFW  
 E\ VDPH OHWWHVLVQLRFRQWGLDWU3" DFFRUGLQJ WR 7XNH\TV WHVW

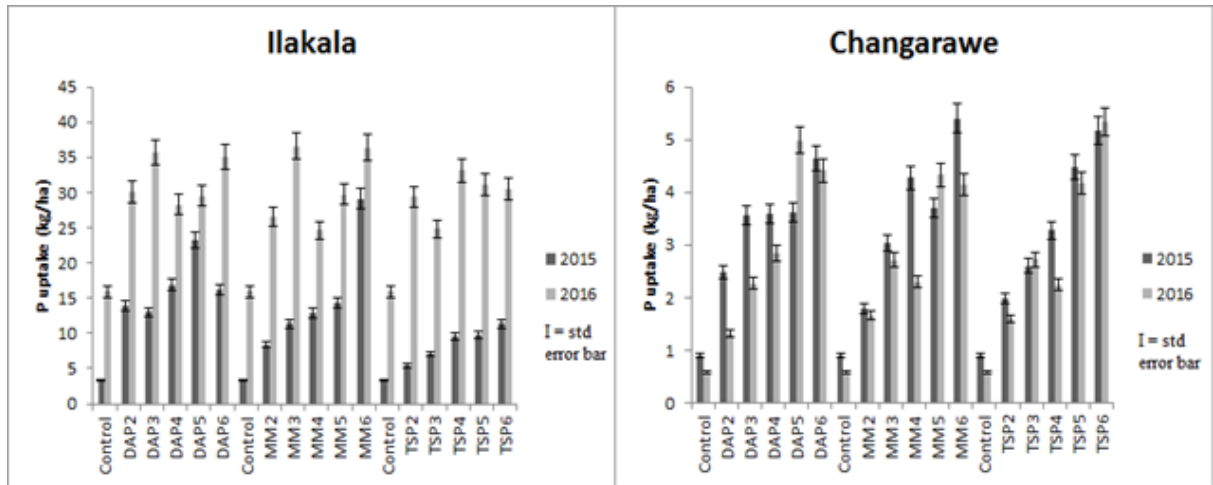
7UHDWPHQW	1	1	3	3	.	.	6	=Q SSP	=Q SSP
'\$3	1.25a	1.88a	0.15a	0.21a	1.39a	1.32a	0.17abcd	5.84c	20.08ghi
'\$3	1.26a	2.35f	0.32i	0.24de	1.93h	2.32cd	0.22g	10.51g	14.97bc
'\$3	1.58d	2.14bc	0.29h	0.25e	1.87g	2.54fg	0.24h	6.19c	21.02jk
'\$3	1.69f	2.66i	0.32i	0.27f	1.84f	2.67i	0.26i	11.16h	19.50efgh
'\$3	1.88h	2.46g	0.40j	0.24de	1.86g	2.27c	0.16ab	7.18d	14.88b
'\$3	1.96i	2.53h	0.27g	0.27f	1.67d	2.36d	0.17abcd	4.54b	14.13a
00	1.26a	1.88a	0.15a	0.21a	1.38a	1.33a	0.157a	5.85c	20.38ij
00	1.47b	2.16c	0.23e	0.27f	1.71e	2.56g	0.17bcde	8.51e	18.82e
00	1.55c	2.45g	0.25f	0.27f	1.67d	2.44e	0.177cde	9.84f	17.23d
00	1.45b	2.73j	0.22d	0.23cd	1.57c	2.32cd	0.22g	9.85f	15.77c
00	1.55c	2.12b	0.23e	0.24de	1.95i	2.04b	0.26i	8.52e	21.51k
00	1.75g	2.17c	0.43k	0.29g	1.54b	2.66hi	0.24h	4.56b	19.74ghi
763	1.25a	1.89a	0.15a	0.21a	1.38a	1.32a	0.16abc	5.71c	20.30hij
763	1.69f	2.24d	0.17b	0.22bc	1.39a	2.53fg	0.19f	3.16a	19.62eghi
763	1.65e	2.31e	0.19c	0.23cd	1.67d	2.62h	0.22g	4.53b	19.62eghi
763	1.77g	2.17c	0.23e	0.27f	2.13j	2.49ef	0.187ef	5.84c	18.82ef
763	1.96i	2.12b	0.22d	0.24d	1.54d	3.29k	0.17abcd	3.23a	18.88ef
763	1.96i	2.52h	0.24e	0.29g	1.55b	2.74j	0.18def	7.15d	19.46efg
0HDQ	1.608	2.265	0.247	0.247	1.669	2.324	0.198	6.789	18.597
3 9DOXH	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
&9	2	1.91	6.1	5.8	1.5	1.75	6.9	4.9	2.4
6(0 "	0.01	0.011	0.003	0.004	0.006	0.018	0.006	0.178	0.288

1XWULHQW FRQFHQWUDWLRQV DW &KDJQDUDZH VWXG\ VLWH ZHUH VL  
 7DEOH 1LWURJHQ LQFUHDVHG IURP FRQWURO WR IHUWLQ]HU UDWLQ  
 UHFRPPHQGHG UDWLQ 00 DQG LQWHUPHGLDWH UDWLQ 763 GXULQ  
 GLIIHUHQW IHUWLQ]HU UDWLQV DQG UHDFKHG PD[LXP DW UHFRPPHQ  
 PLFUR GRVH DQG LQWHUPHGLDWH UDWLQ 3RWDVVLXP FRQFHQWUDWLRQ  
 PD[LXP DW PLFUR GRVH LQWHUPHGLDWH DQG UHFRPPHQGHG UDWLQ  
 RI VXOSKXU LQFUHDVHG ZLWK IHUWLQ]HU UDWLQV IURP GLIIHUHQW  
 &RQFHQWUDWLRQ RI ]LQF ZDV QRW FRQVLVWHQW DQG ZDV GHFUHDVHG  
 FRQFHQWUDWLRQ ZDV YHU\ ORZ FRPSDUHG WR WKH ILUVW \HDU

**Table 3:** 1XWULHQW FRQFHQWUDWLRQ LQ PDLJH SODQV DW &KDQJDUDZH VLW  
 '\$3 LV 'L \$PPRQLXP 3KRVS KDWH \$= \$2 LQG 076-3, 1\*8 7ULSOH 6XSHU 3KRVS KDWH IHUWL  
 IDUPHUV QRW DSSO\LQJ DQGLWLOLJHU DQG DQGDQG DQG NJ 1 KD DQG 3 KD UHVS  
 IROORZHGE\ V DFRWOGH WWHUUVLJGIRLFDQWO\ DW 3" DFFRUGLQJ WR 7XNH\TV WHVW

7UHDWPHQW	1	1	3	3	.	.	6	=Q SSP	=Q SSP
' \$ 3	1.91a	1.46b	0.09a	0.10a	3.73bcd	2.54cd	0.11a	51.18m	38.13e
' \$ 3	2.07c	1.52c	0.10bc	0.11b	3.94de	2.84h	0.21cde	37.42e	32.68cde
' \$ 3	2.33h	1.95h	0.11def	0.12bc	3.40b	2.85h	0.23f	30.84b	28.46abcd
' \$ 3	2.17f	1.88g	0.10bc	0.12bc	3.86cde	3.37j	0.20cd	2234a	34.80de
' \$ 3	1.96b	1.88g	0.10bc	0.20hi	3.55bc	2.62ef	0.21cde	33.08d	23.50abc
' \$ 3	2.14ef	1.70d	0.12fg	0.19fg	4.68g	2.62ef	0.14b	32.36c	24.33abc
00	1.91a	1.51c	0.09a	0.10a	3.73bcd	2.54cd	0.11a	51.18m	38.13e
00	2.13de	1.80f	0.11def	0.13cd	4.15ef	2.66fg	0.23f	53.51n	20.67a
00	2.09cd	1.74e	0.12fg	0.18f	3.02a	2.64ef	0.22def	42.02f	30.59bcde
00	2.58j	1.53c	0.12fg	0.13cd	5.46h	2.34a	0.22def	47.43j	26.11abcd
00	2.25g	1.67d	0.10bc	0.20hi	4.32f	2.62ef	0.20c	42.73g	21.70ab
00	2.77k	2.03i	0.13h	0.16e	5.25h	3.12i	0.22def	50.31l	26.57abcd
7 6 3	1.90a	1.49bc	0.09a	0.10a	3.74bcd	2.47bc	0.11a	50.55lm	37.55e
7 6 3	2.44i	1.37a	0.11def	0.19fg	5.47h	2.58de	0.22def	55.84o	23.30ab
7 6 3	2.34h	1.78f	0.10bc	0.19fg	4.83g	2.54cd	0.22def	47.27j	38.26e
7 6 3	2.44i	1.67d	0.10bc	0.14d	4.11ef	2.46b	0.27h	44.94h	34.80de
7 6 3	2.55j	1.88g	0.12fg	0.21i	3.96de	2.54cd	0.25g	48.17k	21.54a
7 6 3	2.35h	1.81f	0.12fg	0.19fg	4.05def	2.72g	0.21cde	46.25i	25.60abc
0 HDQ	2.24	1.71	0.11	0.15	4.18	2.67	0.2	43.75	28.53
3 9 DOXH	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.079
& 9	6	7.8	18.4	13.4	5.1	6.1	9.8	6.6	19.4
6 (0 "	0.013	0.012	0.003	0.005	0.122	0.022	0.005	0.218	3.149

3KRVS KRUXV XSWDNH DW ,ODNDOD DQG &KDQJDUDZH ZDV DIIHFWHG  
 VKRZQ LQ )LJXUH ,ODNDOD KDG KLJKHU 3 XSWDNH WKDQ &KDQJDUD  
 3 KD DQG WR NJ 3 KD LQ WKH ILUVW \HDU ZKLOH LQ WKH VHFRQ  
 3 KD DW ,ODNDOD DQG &KDQJDUDZH UHVSHFWLYHO\ \$W ,ODNDOD FF  
 ILUVW \HDU KDG ORZ 3 XSWDNH LQ DOO IHUWLLOLJHU W\SHV DQG UDW  
 LQFUHDVHG XS WR '\$3 NJ 3 KD GXULQJ DQG '\$3 NJ 3 KD C  
 XSWDNH LQ 00 DQG 763 LQFUHDVHG ZLWK LQFUHDVLQJ IHUWLLOLJHU  
 ZKLOH GXULQJ WKH VHFRQG \HDU WKH WUHQG GHFUHDVHG DIWHU 00  
 XSWDNH LQ ERWK FURSSLQJ VHDV RQV 7KH VHFRQG \HDU KDG WKH O  
 WKH ILUVW \HDU 7KH 3 XSWDNH LQFUHDVHG ZLWK LQFUHDVLQJ IHUW



DAP is diammonium phosphate, MM is Muringu mazao, TSP is Triple super phosphate fertilizer. Control (farmers not applying fertilizer), fertilizer rates 2 to 6 are 10 and 5, 20 and 10, 40 and 20, 60 and 30, 80 and 40 kg N and P/ha respectively

Figure 2: 3KRVSkruxv xswDNH LQ PDL]H SODQWV DW VL[WK OHDI JURZWK VWDJ

Effects RI IHUWLLOL]HU WISH DQG UDWHV RQ FURS JURZWK

7KH HIIHFV RI IHUWLLOL]HU WISH DQG PLFUR GRVH UDWHV RQ OHDI D  
 VLJQLILFDQWO\ LPSURYHG /\$, FRPSDUHG WR WKH FRQWURO 3  
 VWDJH 5 1R VLJQLILFDQW LQFUHDVH LQ /\$, DW 5 DQG GRXJK JURZ  
 763 NJ 1 DQG NJ 3 KD +RZHYHU DGGLWLRQ RI 00 NJ 1 DQG  
 NJ 1 DQG NJ 3 KD DQG 00 NJ 1 DQG NJ 3 KD \$W 9 JURZV  
 FRQWURO ZKLOH WKH KLJKHVW ZDV LQ 0LQMLQJX PD]DR IHUWLLOL  
 \$W 5 JURZWK VWDJH WKH ORZHVW /\$, ZDV LQ FRQWURO SORVV Z  
 VWDJH WKH ORZHVW /\$, ZDV LQ FRQWURO SORVV ZKLOH WKH KL  
 PD[LPXP DW 5 DQG GHFUHDVHG VOLJKWO\ DW 5

Figure 3: /HDI DUHD LQGH[ /\$, DW YHJHWDWLYH DQG UHSURGXFWLYH VWDJHV X

&URS JURZWK UDWH &\*5 XQGHU GLIIHUHQW IHUWLLOL]HU WISHV DQG  
 JURZWKV VWDJH 9 DQG VLONLQJ 5 WKH UDWH RI JURZWK ZDV JH  
 J PGDLQ GL DPPRQLXP SKRVSKDWH IHUWLLOL]HU DW UHFRPPHQGHQ  
 GRXJK VWDJH 5 WKH UDWH RI FURS JURZWK ZDV LQFUHDVH LQ DW 0



IHUWLLOLJHU UDWHV WKH &\*5GDQEQH'DYHG\*HSHWROO\ &\*B LQFUHDVHG  
FRQWURO DW UHSURGXFWLYH JURZWK VWDJHV ZKLFK GHFUHDVHG UD

Figure 4: &URS JURZWK UDWH &\*5 XQGHU GLIIHUHQW IHUWLLOLJHUV DQG UDWHV

Effect RI IHUWLLOLJHUV RQ \LHOG FRPSRQHQWV JUDLQ DQG WRWDO GUI  
7KH LQIOXHQQFH RI IHUWLLOLJHU W\SHV DQG UDWHV RQ \LHOG FRPSRQ  
QXPEHU RI JUDLQV JUDLQ ZHLJKW DQG JUDLQ \LHOG ZHUH VLJQ  
SRSXODWLRQ DW KDUYHVW ZDV EHWZHHQ DQG LQ 7KH ZKLFK  
QXPEHU RI JUDLQV ZHUH VLJQLILFDQWO\ KLJKHU LQ 00 3 WKD  
IHUWLLOLJHU UDWHV KDG KLJKO\ VLJQLILFDQW QXPEHU RI JUDLQV 3  
GHFUHDVHG VOLJKWO\ WRZDUGV UHFRPPHQGHG UDWH 7KH ZHLJK  
UDWHV 3 DQG LQFUHDVHG ZLWK IHUWLLOLJHU DSSOLFDWLRQ \*U  
UDWHV 3 "WKH \LHOG LQFUHDVHG VLJQLILFDQWO\ ZLWK IHUWLLOLJHU  
DQG GHSHQGHG RQ VHDVRQ %LRORJLFDO \LHOGV LQFUHDVHG ZLWK I

Table 4: (IIFWV RI IHUWLLOLJHU W\SHV DQG UDWHV RQ \LHOG FRPSRQHQWV DQG  
ZKHUH DQG DQG DQG DQG DQG DQG DQG NJ 1 DQG 3 KD UHVS  
IROORZHG E\ <math>P</math> <math>P</math> <math>P</math> <math>P</math> <math>P</math> <math>P</math> <math>P</math> <math>P</math> <math>P</math> <math>P</math> <math>P</math>  
IROORZHG E\ <math>P</math> <math>P</math> <math>P</math> <math>P</math> <math>P</math> <math>P</math> <math>P</math> <math>P</math> <math>P</math> <math>P</math> <math>P</math>  
IROORZHG E\ <math>P</math> <math>P</math> <math>P</math> <math>P</math> <math>P</math> <math>P</math> <math>P</math> <math>P</math> <math>P</math> <math>P</math> <math>P</math>

7UHDW	PHQW P	* UDLCV P	J*UDLQ ZW J	J*UDLQ LHOG NJ KD	J*UDLQ LHOG KDUYHVW NJ KD	DW J	J*UDLQV P	J*UDLQV ZW J	J*UDLQ LHOG NJ KD	J*UDLQ LHOG KDUYHVW NJ KD	'0 DW
)HUWLLOLJHU											
DAP	3.83a	679.1a	34.69a	2373a	511.3ab	4.05a	1584a	32.59a	2596a	827.2a	
MM	4.03a	754.5b	35.51a	2707b	539.9 b	4.16b	1580a	33.01a	2635a	841.4a	
TSP	3.86a	680.2a	35.00a	2396a	488.1 a	3.98a	1671a	33.58a	2721b	846.1a	
Mean	3.91	704.6	35.07	2492	513.1	4.06	1612	33.06	2651	838	
CV (%)	3.4	3.12	5.92	3	1.9	0.43	19.5	6.9	1.2	16.7	
SEM	0.05	16.91	0.74	2.2	14.38	0.028	74	0.539	1.52	32.9	
P value	0.06	0.003	0.731	0.001	0.003	0.025	0.622	0.436	0.01	0.915	

5 DWHV										
1	3.99 a	409.1a	28.20a	1152a	313.0 a	4.12a	992a	29.3a	1492a	496.8a
2	3.89a	586.1b	35.42b	2064b	424.8 b	4.03a	1470b	33.07b	2394b	855.0b
3	3.90a	775.7c	37.62b	2888c	578.9 c	4.01a	1782b	33.12b	2590c	841.8b
4	3.84a	829.3c	35.87b	2930c	587.2 c	3.99a	1798b	34.24b	2938d	900.2b
5	3.93a	803.3c	36.90b	2938c	596.1 c	4.08a	1840b	34.25b	3229e	953.2b
6	3.92a	824.0c	36.38b	2980c	578.5 c	4.07a	1787b	34.40b	3264e	982.6b
Mean	3.91	704.6	35.07	2492	513.1	4.06	1612	33.06	2651	838
CV (%)	2.6	3.12	5.92	3.8	1.9	1.4	19.5	6.9	1.1	16.7
SEM	0.048	23.91	1.04	3.12	20.24	0.042	104.6	0.763	2.02	46.6
P value	0.38	0.001	0.001	0.001	0.001	0.429	0.001	0.001	0.001	0.001

\$W & KDQJDUDZH VLWH HIIHFWV RI IHUWLLOLJHU W\SHV DQG UDWHV RQ WKH QXPEHU RI JUDLQV DQG JUDLQ \LHOGV ZHUH VLJQLILFDQWO\ KLKDUYHVW ZDV EHWZHHQ 7KH DQG QXPEHS ODQWDLQV LQFUHDVHG VLJQLILFDQWO\ GXULQJ DQG DW 3 DQG IRU IHUWLLOLJHU W\SHV KXQGUHG JUDLQV ZDV KLJKO\ VLJQLILFDQW LQ IHUWLLOLJHU UDWHV KLJKO\ VLJQLILFDQW LQ IHUWLLOLJHU W\SHV DQG UDWHV RQ 7KH JUDLQV IHUWLLOLJHU UDWHV XS WR LQWHUPHGLDWH UDWHV DQG DQG GHWHUPLQHG ZDV KLJKO\ LQIOXHQFHG E\ VHDVRQV ZKHUH KLJKHU \LHOGV DYHUDJH ZHUH ORZ DYHUDJLQJ NJ KD %LRORJLFDQ \LHOGV LQFUHDVHG ZL

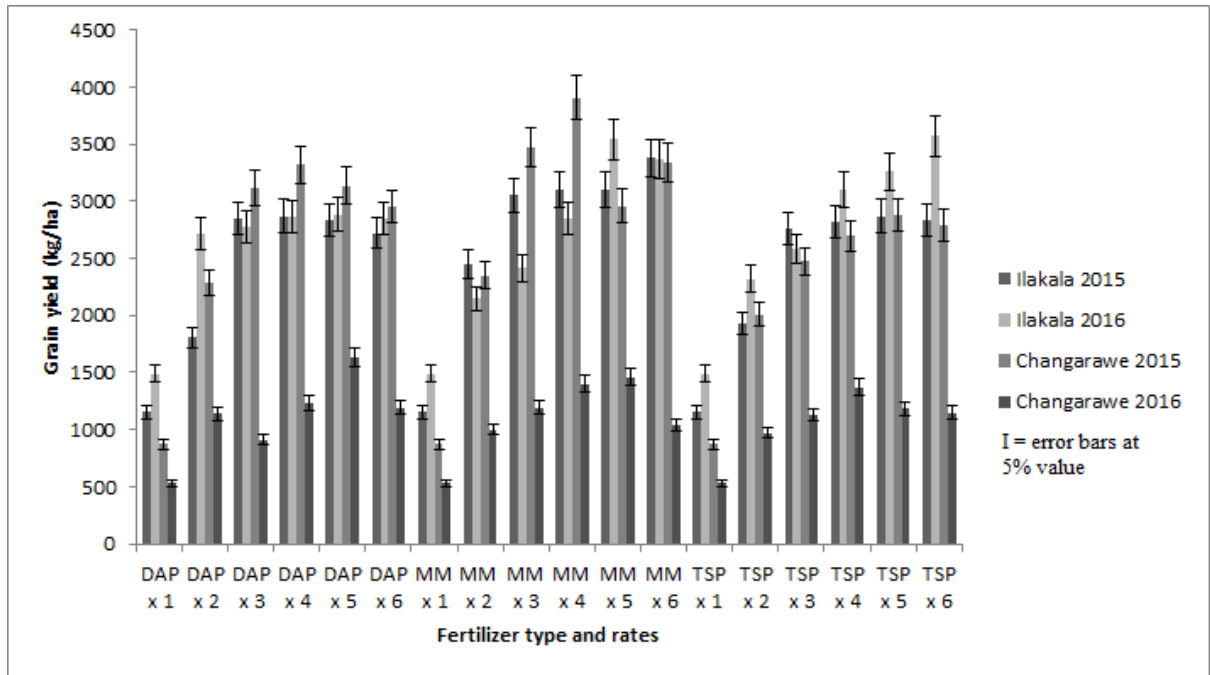
**Table 5:** (IIFWV RI IHUWLLOLJHU W\SHV DQG UDWHV RQ PDLJH \LHOG FRPSRQHQB :KHUH DQG DQG DQG DQG DQG DQG DQG NJ 1 DQG 3 KD UH IROORZH D EHWZHHQ GR QRW GLIIHU VLJQLILFDQWO\ DW 3" DFFRUGLQJ WR 7XNH\

7UHDWPHQW	3ODQW P	JUDLQV P	*JUDLQV ZW J	JUDLQ NJ KD	\LHOGV J	DW 3ODQW P	JUDLQV P	*JUDLQV ZW J	JUDLQ NJ KD	\LHOGV J
)HUWLLOLJHU D										
DAP	3.86a	853.7b	30.33a	2615b	859.4a	3.95ab	378.3b	29.15a	1107b	813.8b
MM	4.03b	946.2c	29.41a	2819c	897.6a	3.99b	366.0ab	29.80a	1105b	625.8a
TSP	3.89a	745.7a	30.16a	2287a	861.0a	3.89a	349.9a	29.75a	1056a	628.9a
Mean	3.924	849	29.97	2572	872.7	3.95	364.7	29.57	1089.3	689.5
CV (%)	2.9	6.6	1.4	6.6	2.5	2.1	3.6	2.2	3.6	10.3
SEM	0.03	29.1	0.812	9.17	21.44	0.024	4.01	0.231	0.752	12.92
P value	0.001	0.001	0.485	0.01	0.147	0.018	0.019	0.199	0.005	0.001
5 DWHV E										
1	3.86a	352.5a	24.84a	874a	512.9a	3.90a	218.8a	24.55a	530a	454.0a
2	3.96a	729.0b	30.71b	2215b	717.8b	3.95a	376.4b	27.97b	1037b	601.8b
3	3.91a	957.5c	31.67b	3023cd	879.1c	3.89a	354.3b	30.48c	1076bc	662.0b

4	3.88a	1095.7d	30.65b	3309d	1000.8d	3.98a	433.1c	31.04c	1336d	808.0c
5	3.96a	988.9cd	30.55b	2992c	1067.7d	4.02a	441.9c	32.36d	1428e	792.4c
6	3.99a	967.7c	31.39b	3029cd	1057.6d	3.94a	364.0b	31.01c	1130c	818.9c
Mean	3.92	849	29.97	2572	872.7	3.95	364.7	29.57	1089.3	689.5
CV (%)	1.7	6.6	1.4	8	2.5	1.7	2.5	1.7	1.5	10.3
SEM	0.034	41.1	1.148	6.47	30.32	0.034	8.84	0.279	1.736	18.27
P value	0.065	0.001	0.001	0.001	0.001	0.088	0.001	0.001	0.001	0.001

, QWHUDEFWLRQ IHHFW RI IHUWLLOLJHU W\SHV DQG UDWHV RQ JUDLQ ILHOG

7KH LQWHUDEFWLRQ IHHFW EHWZHHQ IHUWLLOLJHU W\SHV DQG UDWHV DQG VHFRRQG \HDU )LJXUH 7KHUH ZDV D SRVLWLYH LQFUHDVH IUR IHUWLLOLJHU DQG WKHUHDIUHU \LHOG GHFUHDVHG WRZDUGV UHFRPP REVHUYHG GXULQJ WKH VHFRRQG FURSSLQJ VHDV RQ LQ ERWK YLOODJ



DAP is diammonium phosphate, MM is Minjingu mazao, TSP is triple super phosphate fertilizer. Rate 1 is control (farmers not applying fertilizer), rates 2 to 6 are 10 and 5, 20 and 10, 40 and 20, 60 and 30, and 80 and 40 kg N and P/ha, respectively.

Figure 5: , QWHUDEFWLRQ IHHFW RI IHUWLLOLJHU W\SHV DQG UDWHV RQ JUDLQ ILHOG

7KH UHVXOWV LQGLFDWHG D KLJK IHHFW RI WKH IHUWLLOLJHU UDWHV )LJXUH 7KH 5 YDOXH ZHUH DQG DW ,ODNDOD DQG D VHDV RQ UHVSHFWLYHO\

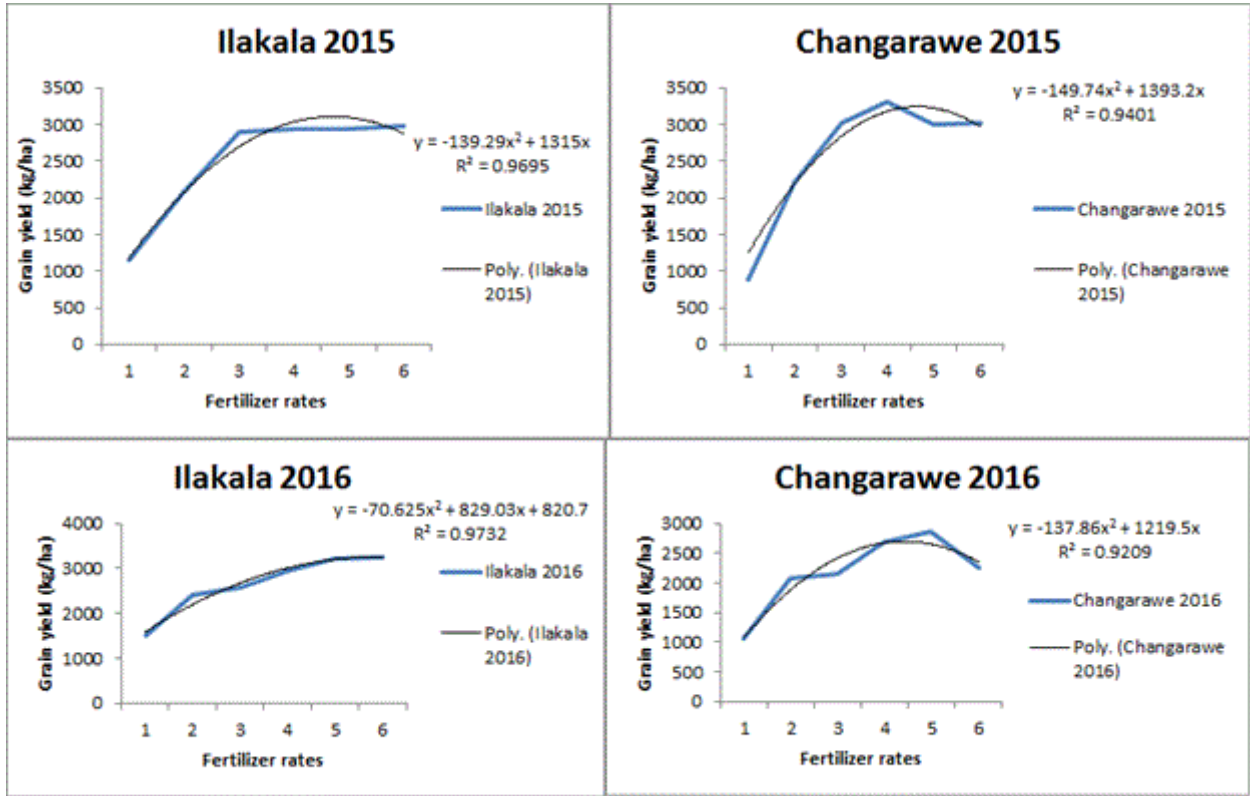


Figure 6: 5HODWLRQVKLS EHWZHHQ 1 DQG 3 UDWHV DQG PDLJH \LHOG DW ,ODNDOD  
 \$JURQ ~~Effectiveness~~ RI IHUWLLOLJHUV XVHG

5HODWLYH DJURQRPLF HIIHFWLYHQHV 5\$( RI 0LQMLQJX 0D]DR 00  
 IHUWLLOLJHUV LV VKRZQ LQ 7DEOH \$W ,ODNDOD VLWH GXULQJ  
 DERYH WKH VWDQGDUG IHUWLLOLJHUV '\$3 DQG 763 UHVSHFWLYHO\ '  
 IHUWLLOLJHU ZDV DERYH '\$3 DQG EHORZ WKH 763 DV VWDQGD  
 GXULQJ ZDV DQG DERYH WKH VWDQGDUG IHUWLLOLJHUV  
 5\$( ZDV DQG DERYH WKH VWDQGDUG IHUWLLOLJHUV '\$3 DQG 763

Table 6: 5HODWLYH DJURQRPLF HIIHFWLYHQHV 5\$( RI 0LQMLQJX 0D]DR DJDLQ  
 GHVFULSWLYH VWDWLVLV

)HUWLLOLJHU W\SH	,ODNDOD		&KDQJDUDZH	
	5\$(	5\$(	5\$(	5\$(
DAP	100	100	100	100
MM	136.5	102	111.1	107.2
CV (%)	27.14	40.05	11.53	38.6
SEM	16.57	18.27	5.73	18.5
TSP	100	100	100	100
MM	129.4	90.86	138.5	109.2
CV (%)	16.69	16.17	18.87	19.44
SEM	9.66	6.67	11.68	9.5

,6&866,21

6RLO FKDUDFWHULVWLFV DQG ZHDWKHU FRQGLWLRQ

6RLOV DW ,ODNDOD VLWH ZHUH FKDUDFWHULJHG E\ VDQG\ ORDP DQG VXLWDEOH E\ PRVW FURSV > @ 6RLOV ZHUH FKDUDFWHULJHG E\ ORZ ZHDWKHUHG DQG OHDFKHG DV UHSRUWHG E\ 6]LODV HW DO > @ 0 PHGLXP VRLO S+ ZKLFK ZDV EHWZHHQ DQG ZKLFK ZDV LGHDO IRU HW DO > @ =LQF ZDV EHORZ D FULWLFDO OHYHO RI PJ NJ UHTXLU E\ =Q 3 DQWDRQLVP DQG VRLO S+ LQ ,ODNDOD > @

,Q &KDQJDUDZH VRLOV WH[WXUH ZDV VDQG\ FOD\ ORDP DQG VDQG\ RI EDVLF FDWLRQV FDXVHG E\ KLJK UDLQV LQ WKH DUHD DV REVHUY ORZ PDLQO\ GXH WR KLJKO\ ZHDWKHUHG DQG OHDFKHG VRLOV /RZ DFWLYLWLHV DQG QLWULILFDWLRQ RI RUJDQLF PDWWHU FRQWULEXW DOVR SKRVSKDWH LRQV SUREDEO\ FRPELQHG ZLWK LURQ DQG DOXP /RZ ]LQF LQ WKH VRLO EHORZ D FULWLFDO OHYHO RI PJ NJ UHTXLU DFLGLF VRLO LQ &KDQJDUDZH > @ 7KHVH ILQGLQJV DUH LQ DJUHF JRGH > @

9DULDWLRQV LQ UDLQIDOO DPRXQW DQG GLVWULEXWLRQ EHWZHHQ , GLVWDQFH IURP HDFK RWKHU DQG GLIIHUHQFHV LQ JHRJUDSKLFDO O DQG FKDUDFWHULJHG E\ KLJK YHJHWDWLRQ FRYHU VXFK DV IRUHVW SDWWHUQ EHWZHHQ WKH WZR FURSSLQJ VHDVQV FKDUDFWHULJHG ODQ\RQL 7DQJDQLD > @ DQG \$FFUD \*KDQD > @ 7KLV LQWHU VHDV KDYH EHHQ LQIOXHQFHG E\ WKH LPSDFW RI FOLPDWH FKDQJH > @

1XWULHQW FRQFHQWUDWLRQ LQ PDLJH FURS

7KH GHILFLHQF\ RI 1 GXULQJ DQG 7DEOHV DQG ZDV UHIO 1 ZDV LPSURYHG E\ IHUWLLOL]HU DSSOLFDWLRQ 1 FRQFHQWUDWLRQ GXULQJ DW &KDQJDUDZH GXH WR JRRG UDLQIDOO SDWWHUQ IUR DYDLODELOLW\ DQG XSWDNH ZDV DIIHFWHG E\ VRLO PRLVWXUH > @ DUH DGHTXDWH IRU PDLJH SURGXFWLRQ 1LWURJHQ FRQFHQWUDWLR WUHQG UHSRUWHG E\ 0DXULFH HW DO > @

3KRVSKRUXV ZDV ZLWKLQ DGHTXDWH UDQJH RI UHSRUWHG E\ 7DEOH IRU ERWK FURSSLQJ \HUV GXH WR IHUWLLOL]HU DSSOLFDW DYDLODELOLW\ DQG XSWDNH E\ SODQWV DV UHSRUWHG E\ /DQGRQ > GHILFLHQW LQ SODQWV 7DEOH UHIOHFWLQJ SRRU VRLO IHUWLLOL ]HEUXDU\ LQFUHDVHG QXWULHQW ORVV DQG UHGXFHG QXWULHQW XS

3RWDVVLXP ZDV GHILFLHQW LQ ZKLOH WKH FRQFHQWUDWLRQ LQ &KDQJDUDZH . ZDV DGHTXDWH 7DEOH UHIOHFWHG LQ VRLO IH QXWULHQWV VXFK DV QLWURJHQ DQG SKRVSKRUXV FRQFHQWUDWLRQ 9 ZKLFK SURPRWHG URRW JURZWK DQG H[SDQVLRQ IRU QXWULHQW > @ +RFKPXWK HW DO > @ UHSRUWHG WKDW FRQFHQWUDWLRQ R &RQFHQWUDWLRQ RI VXOSKXU ZDV GHILFLHQW LQ DOO WUHDV +RZHYHU 1 WR 6 UDWLR ZDV EHORZ LQGLFDWLQJ WKDW 6 ZDV LG GHILFLHQW LQ SODQWV DW ,ODNDOD 7DEOH ZKLOH DW &KDQJDUDZH \HUV GXH WR LQFUHDVH DFLGLW\ LQ WKH VRLO DV UHSRUWHG E\ /

7KH SKRVSKRUXV 3 XSWDNH LQ PDLJH SODQW DW ,ODNDOD ZDV KLJK ,ODNDOD KDG PHGLXP 3 ZKLOH &KDQJDUDZH KDG YHU\ ORZ 3 LQ WKH VLWH DUH LQ WKH UDQJH UHSRUWHG E\ 0XKDZLVK HW DO > @ WF ,ODNDOD 3 XSWDNH ZDV KLJKHU DW PLFUR GRVH UDWHV DQG WR PHGLXP VRLO 3 ZKLFK SUREDEO\ QHHGHG RQO\ VPDOO UDWHV IR

7KH WUHQG RI 3 XSWDNH DW ,ODNDOD ZDV KLJKHU LQ WKH VHFRQG \ GLVWULEXWLRQ RI UDLQIDOO EHWZHHQ VHHGOLQJ DQG VL[WK OHDI J FGDUDFWHULJHG E\ SURORQJHG GU\ VSHOO )LJXUH ZKLFK DIIHF &KDQJDUDZH ZKLFK KDG KLJKHU QXWULHQW XSWDNH LQ WKH ILUVW VSHOO IURP WKLUG ZHHN WR VL[WK ZHHN DIWHU SODQWLQJ )LJXUH VWDJH DQG DIIHFWHG QXWULHQW XSWDNH GXH WR PRLVWXUH VWUHV HVSHFLDOO\ 3 ZDV KLJKO\ DIIHFWHG E\ PRLVWXUH VWUHV LQ WKH V

*&URS JURZWK ILHOG DQG ILHOG FRPSRQHQWV*

\$V H[SHFWHG /\$, ZDV ORZ DW VL[WK OHDI JURZWK VWDJH EXW DQG WKHUHWHU GHFUHDVHG JUDGXDOO\ WR DW GRXJK JURZWK DO > @ /\$, ZDV WKH ORZHVW LQ FRQWURO SORWV WKLV UHIOHF QLWURJHQ LQ WKH VRLO ZLWK ORZ IHUWLWLW\ VWDWXV 7DEOH IRU 7KH UHSRUWV E\ )DJHULD HW DO > @ DQG 1JXD 5REHUWVRQ HW D 6RPH SORWV WUHDWHG ZLWK IHUWLWLW]HU KDG /\$, EHORZ WKH RSWL 9 WDVVHOLQJ 97 DQG VLONLQJ 5 JURZWK VWDJHV )LJXUH

&URS JURZWK UDWH &\*5 LQFUHDVHG IURP VL[WK OHDI JURZWK VWDJH GXH WR LQFUHDVHG SKRWRV\QWKHVLV ZKLFK LV LQIOXHQFHG E\ OH UHVXOWHG LQWR PRUH GU\ PDWWHU DFFXPXODWLRQ DQG FURS JUR U E\ 3RUWHV HW DO > @ 6XFK UHVXOWV ZHUH DOVR UHSRUW GD\LQ 1LJHULD DQG EHWZHHQ WDVVHOLQJ > @ ,Q FRQWURO WUHD GHFUHDVLRQ IURP VLONLQJ 5 WR GRXJK VWDJH 5 GXH WR ORVV UHSRUWHG E\ +RNPDOLSRXU HW DO > @

)HUWLWLW]HU W\SHV DQG UDWHV DSSOLHG UHVXOWHG LQWR LQFUHDV 7 +D VVFK UHVXOWV KDYH DOVR EHHQ UHSRUWHG E\ .LVHWX HW DO VKRZ WKDW HYHQ XQGHU XQUHOLDEOH UDLQIDOO FRQGLWLRQV IDUP REVHUYHG E\ 'H \*URRWH HW DO > @ LQ 7DQ]DQLD DQG LQ :HVW \$IU 0D]DR 00 ZDV WKH EHVW IHUWLWLW]HU IRU XVH XQGHU IDUPHUV FRQ NJ KD ZKLFK ZDV DQG PRUH WKDQ '\$3 DQG 763 UHVSHFWLY FRQWHQW DQG DELOLW\ WR VXSSO\ ERWK PDFUR QXWULHQWV 1 3 QXWULHQW FRQFHQWUDWLRQ LQ SODQWV 7DEOHV DQG QXWULHQ GRVH UDWHV DW NJ 1 DQG NJ 3 KD DQG NJ 1 KD DQG NJ NJ KD LQ ,ODNDOD NJ KD LQ &KDQJDUDZH GXULQJ 7KH WUHQG RI \LHOG LQFUHDVH UHSRUWHG LQ WKLV VWXG\ LV VLPL > @ +RZHYHU DW &KDQJDUDZH YLOODJH GXULQJ UHVXOWV ZHUH SODQWLQJ )LJXUH )HUWLWLW]HU UDWHV NJ 1 DQG NJ 3 KD D VDPH DV UHFRPPHQGHG UDW 2XU VWXG\ ZDV FDUULHG RXW LQ RQ UHSUHVHQWDWLYH IRU ODUJH VXE KXPLG WURSLFDO UHJLRQV ZLWK HFRORJLFDO ]RQH > @

*)HUWLWLW]HU E\ VPDOOKROGHU IDUPHUV*

7KXV LW LV VXJJHVWHG WKDW WKH UHSRUWHG UDWHV DQG IU UHFRPPHQGDWLRQ RI NJ 1 DQG NJ 3 KDIRU WKH HDVWHUQ ]RQH )XUWKHU WKH FXUUHQW UHVXOWV IURP PLFUR GRVLQJ UDWHV RI 1 3HUVRQDO &RPPXQLFDWLRQ ,Q PRVW \$JUR VKRSV IRXQG LQ 7DQ]DQ NJ ZKLOH '\$3 DQG 763 DUH VROG DW SHU NJ EDJ 7KH LQGLFDWHG WKDW 0LQMLQJX 0D]DR 00 IHUWLWLW]HU KDG 5\$( PRUH VXSHULRU WR '\$3 DQG 763 XVHG DV D VWDQGDUG IHUWLWLW]HUV XVH VRXUFH RI 3 ZLWK KLJKHU 5\$( 7KLV UHVXOW LV LQ DJUHHPHQW ZLW URFN IHUWLWLW]HUV ZLWK ORZ DQG PHGLXP 3 VROXELOLW\ KDG KLJK 763

7KH UHVXOWV UHSRUWHG RQ JUDLQ LQ WKLV VWXG\ DUH VOLJKWO UHVHDFKHUV ZKR KDYH ZRUNHG XQGHU 7DQ]DQLD IDUPHUV ILHO

E\ UHODWLYHO\ ODUJH JUDLQ VLJH UHSRUWHG LQ WKLW VWXG\ WKDW UHSRUWHG LQ WKLW VWXG\ ZDV DOVR IRXQG WR ~~WR~~ VLJQLILFDQWO\ F

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0LQMLQJX 0D]DR IHUWLLOL]HU SHUIRUPHG EHWWHU WKDQ '\$3 DQG 763 E\ DQG DW NJ 1 DQG NJ 3 KD RI UHFRPPHQGHG UD UHFRPPHQGHG UDWH WKDQ FRQWURO UHVSHFWLYHO\ ,QWHUPHGLD DW NJ 1 DQG NJ 3 KD RI UHFRPPHQGHG UDWH DQG NJ UDWH FRPSDUHG WR UHFRPPHQGHG UDWH NJ 1 DQG NJ 3 KD U \$ FRPELQDWLRQ RI IHUWLLOL]HU UDWH ~~U~~ UHFRPPHQGHG UDWH ~~KDV~~ ZHO NJ 3 KD RI UHFRPPHQGHG UDWH DUH WKH DSSURSULDWH PLFUR GRV VLWH DQG RWKHU DUHDV ZLWK VLPLODU FRQGLWLRQV 7KH IHUWLLOL FURS SURGXFWLYLW\ XQGHU VPDOOKROGHU IDUPLQJ \V\WHPV LQ VXE 1 DQG NJ 3 ~~RD~~ UHFRPPHQGHG UDWH DV ZHO ~~RV~~ UHFRPPHQGHG UDW UHFRPPHQGHG WR UHSODFH NJ 1 DQG NJ 3 KD IRU UHVRXUFH H UDWHV \$OVR IHUWLLOL]HU SDFNDJH KDV WR LQFOXGH ORZHU DPRXQ GRVH VWUDWHJ\ DQG DIIRUGDELOLW\ WR UHVRXUFH SRRU IDUPHUV LPSRUWDQW WR DYDLO ORFDOO\ SURGXFWG FKHDS IHUWLLOL]HUV L HIIHFWLYHQHV

\$&.12:/('\*(0(17

7KLV ZRUN LV D SURGXFW RI WKH 7UDQV 6(& SURMHFW IRU IRRG VHF RI (GXFDWLRQ DQG 5HVHDFK %0%) DQG WKH \*HUPDQ\ )HGHUO 0LQ %0=

5() (5(1&(6

- > @ 6XOHLPDQ 5 \$ DQG 5RVHQWUDWHU 2015\$ 0\$FKLJDQ ,RZD 6WDW
- > @1\$3 1DWLRQDO \$JULFXOWXUDO 3ROLF\ 'DU HV VDODDP 7DQ]DQ &RRSHU2D]WLSHV
- > @ %HQGHU \$5UR2D]W DO S
- > @0DUDQG \$ ( 0ERJRQL - ' DQG /H\ \* - 7DQ]DQLD 0LQLVW &RRSHU2D]WLSHV
- > @ 'UXLOKH = DQG %DUUHLUR +XUOH - 5RPHS)\$2 (6\$ :RUNLQJ S
- > @ &DPDUD ,QW HUH-W2000L 6FLS
- > @ \$XQH - % DQG &RXOLEDO\ \$ 6 2015W]SUODQG 6SULQJHU ,QWHU
- > @ \$XQH - % DQG %D 2008RWR S\$
- > @ 0XUHQGR & D, 6, 6 2005QSL 0
- > @ 2NHEDODPD \$I& -%\$JU2007 BEVS
- > @ \$GDPV \$10XWHV&FO \$2006RHFVS\ VW
- > @ +D\DVKL1XWHUW\DO \$2006RHFVS\ VW
- > @ 3DOH 6 0DVRQ 66&\$IDQ-G3 0D]DQ 6RS60-
- > @ 6LPH \* DQG \$XQ]RQRP\ S
- > @ 2NHODEDPDR&O%6FH 2006FO\$P S
- > @ .LVLQ\R 3 2 DQ-\$3DDE \$FO]R2016 7HFKQRO
- > @PXUL 1 HW DO .HQ\D 6RLO 6FLHQFH 6RFLHW\ RI (DVW \$IULFD \$IULFDQ 6RLO 6FLHQFH 2016 RSLHW\ &RQIHUHQFH
- > @ \*UDHI ) HW DO 2014ORE \$RRG 6HFXULW\
- > @ .DMPEH \* & HW DO /RQGRQ 8. ,QWHUQDWLRQD2013,QVWLWXV
- > @ /\LPR 6 0GXUXPD =\$IDQ-\$GU2014USRVS H +
- > @ 0F&ODXOH\ \$ -RQHV & DQG -DFREVH2009 S0RQWDQD 0RQWDQ

- > @HUWLLOLJHUV 0LQMLQJX 0LQHV DQG 'HYHORSLQJ LQGLJHQRXV UH  
7DQJDQLD 0LQMLQJX 0LQHV DQG )HUWLLOLVHU /WG
- > @HUWLLOLJHUV DQG WKHLU XVH \$ SRFNHW JXLGH IRU H[WHQVLRQ R  
)\$2 RI WKH 8QLWHG 1DWLRQV ,QWHUQDWXUDO )HUWLLOLJHU ,QG
- > @RQWJRPHU\ ' & 'HVLJQ DQG DQDO\VLV RI H[SHULPHQWV S1HZ <F
- > @ 3UDVDG 5 DQG 3RZHU - ) 1HZ <RUN 1998 6\$ & 5& 3UHVV /HZLV 3
- > @DQ\HND ( .DPDOD 5 DQG .DVXJD 5 'HSDUWPHQW RI 5HVHD  
\$JULFXOWXUH )RRG 6HF 2007LVS\ DQG &RRSHUDWLYHV
- > @ 6WDII 6RLO 6XUYH\ 'HSDUWPHQW RI \$JULFXOWXUH 1DWXUDO 5
- > @RFKPXWK \* HW DO ,QVWLWXWH RI )RRG DQG \$JULFXOWXUDO  
6FLH 2012HVS
- > @ )DJHULD 1 . %DOLJDU 9 & DQG -RQH 1997 & \$\$ 1HZ <RUN 0DUFH
- > @ 2JRNH , - (JHVL & 1QVWQG\$ 2BLH 2002DDOS&HY
- > @ ,00<7 <LHOG DQG \LHOG FRPSRQHQWV \$ SUDFWLFDO JXLGH IRU  
,QWHUQDWLRQDO 0DLJH DQG :KHDW 2013SSRYHPPHQW &HQWHU &,00<
- > @RPH] . \$ DQG \*RPH] \$ \$ 6WDWLVLWLFDO SURFHGXUHV IRU DJUL  
1984 S
- > @ 0XKDZLVK 1 0 DQG 6NDJ\WT8Q 2009 \$JUSF 6FL
- > @DQGRQ - 5 \$ KDQGERRN RI VRLO VXUYH\ DQG DJULFXOWXUDO O  
S
- > @ 6JLODV\$RWDH\$WDLFXOWXUH6HF6FLDQG%QDRILO2006G 3ODQW 6FLHQFH
- > @ )RWK + ' DQG (OLV % \* 6RLO 1997HUWLLOLW\ )ORULGD &5& 3UH
- > @ 0DU\ \$ / DQG\$0DMXQL\$(Q2009L 7HFKQRO
- > @ \*HUPHU - \$GGDL- )6HOGG&DUXSH5HVSUQ
- > @ / HW DO 'DU HV VDODDP 7KH &OLPDWH &KDQJH ,PSDFWV \$G  
3URFHGHGLQJV RI WKH ILUVW FOLPDWH FKDQJH LPSDFWV PLWLJD  
2012 S
- > @ 0RXULFH 7DQJDQWDD-2014ULF 6FL
- > @ 3RUWHV 7 ' DQ\$6WGH6FLDQW\BUSP
- > @ 1JX\D 5REHUV\$VRRQ\$012HW DQ
- > @ 6DQL %\$DU -H\$W 2004 5HVS
- > @ \$GHSR ) \$ DQ\$J2010R0AFL \*S
- > @ +RNPDOLSRXU 6 DRUGO Q \$ 500 6IFLOS+
- > @ .LVHWX- \$JUH 3R014F\ 5BV
- > @ GH \*URRWYHGG &HVS 5HVS
- > @5% ,866 :RUNLQJ \*URXS :RUOG 5HIHUHQFH %DVH IRU 6RLO 5HV  
FODVVLILFDWLRQ V\WHP IRU QDPLQJ VRLOV DQG FUHDWLQJ OH  
2UJDQLJDW 2015Q S)\$2
- > @ 'URXJKW 7ROHUDQW 0DLJH IRU \$014LFD '70\$ D TXDUWHUO\ UHSR